Coronary Artery Aneurysms Following Repair of Transposition of the Great Arteries

Nikkan Das, MD, Nazia Husain, MBBS, MPH, Jyothy J. Puthumana, MD, Michael R. Carr, MD, and Shivani G. Patel, MBBS, MS, *Chicago, Illinois*

INTRODUCTION

Kawasaki disease (KD), an acute medium-vessel vasculitis, can lead to coronary artery aneurysms (CAAs). In rare cases, new aneurysms may be detected remotely from the acute disease process and after the typical clinical manifestations have resolved. In patients with repaired congenital heart disease, this diagnosis may be confounded by a history of instrumentation of the coronary arteries. We describe a patient with multiple CAAs in the setting of repaired d-loop transposition of the great arteries (TGA) with suspected, undiagnosed history of KD.

CASE PRESENTATION

A 16-year-old young man with TGA initially underwent a balloon atrial septostomy in infancy followed by an arterial switch operation (ASO). Notably, the native coronary artery anatomy demonstrated anomalous origin of the circumflex coronary artery from the right main coronary artery (RCA) originating from the anterior and rightward sinus and the left anterior descending coronary artery (LAD) originating from the leftward sinus. At the time of ASO, the RCA was extensively mobilized. In the immediate postoperative period, the patient developed ST segment changes and on surgical inspection was noted to have kinking of the circumflex coronary artery. They were placed back on bypass, and the circumflex coronary artery was further dissected to relieve the slight obstruction with significant improvement. The patient did well in the postoperative period and was maintained on aspirin. Serial echocardiography demonstrated progression in neoaortic dilation and neoaortic regurgitation, as expected in a patient after ASO, for which atenolol was started. Approximately 10 years after the ASO, there was progressive left ventricular (LV) dilation with no evidence of dysfunction. There was also mild left pulmonary artery stenosis, which was hemodynamically insignificant. The patient never manifested any cardiac symptoms. There was no other medical history. Specifically, there was no obvious history of prolonged fever, rash, mucosal changes, or extremity swelling. Laboratory data were notable for a normal lipid panel. Exam demonstrated a grade 2 to 3/6 systolic ejection murmur at the left upper sternal border, consistent with left pulmonary artery stenosis. A transthoracic echocardiogram (TTE) 1 year prior demonstrated known moderately dilated neoaortic root (4.0 cm, *Z* score +5.5) with mild regurgitation (Figure 1) and a moderately dilated left ventricle (LV; LV end-diastolic volume [LVEDV] 213.6 mL, *Z* score +4.9; Figure 2) with low normal systolic function (LV ejection fraction [LVEF] 52%; Videos 1 and 2). The coronary arteries were not well visualized on TTE.

Based on routine cardiac imaging guidelines in TGA patients, as well as monitoring of the neoaortic root dilation, the patient underwent cardiovascular magnetic resonance (CMR). The CMR was notable for focal severe aneurysmal dilation of the mid-RCA in the right atrioventricular groove measuring up to 6 mm in diameter and 10 mm in length, in addition to a severely dilated neoaortic root (42.4 × 42.9 × 43.8 mm, *Z* score +6.4) with mild regurgitation and a mildly dilated LV (indexed LVEDV 124 mL/m^2, *Z* score +2.9) with low normal systolic function (LVEF 54%). There was no evidence of regional wall motion abnormalities. The right ventricle (RV) was mildly dilated (indexed right ventricular end-diastolic volume [RVEDV] 121 mL/m^2) with normal global systolic function (right ventricular EF 55%; Video 3).

Given this finding, a cardiac computed tomography scan (CCT) was obtained, which demonstrated multiple CAAs (Figure 3). There were 2 focal severe aneurysms in the RCA (1 in the mid-RCA atrioventricular groove with associated calcifications measuring 8.6 × 8.8 mm in diameter and 14.4 mm in length and 1 in the distal RCA just prior to continuation as the posterior descending coronary artery measuring 7.0 × 7.9 mm in diameter and 9.8 mm in length with no thrombus) and 1 long-segment moderate aneurysm with calcification in the proximal LAD measuring 5.7 × 6.2 mm in diameter and 11.7 mm in length. The degree of dilation was based on visual estimate as well as comparison to dimensions of the coronary origins.

These findings prompted initiation of coumadin and a statin. To further assess for vascular abnormalities, magnetic resonance angiography of the head, neck, and abdomen was obtained with no evidence of aneurysms. The patient then underwent exercise single-photon emission computed tomography (SPECT) myocardial perfusion imaging. After exercise for 11 minutes and 22 seconds using the Bruce protocol, 87% of maximum predicted heart rate was achieved with no symptoms and no definite electrocardiographic evidence of ischemia. Following exercise, imaging demonstrated a predominantly fixed perfusion defect in the basal and mid segments with normal wall motion. To better evaluate this, the patient underwent prone imaging, which demonstrated a decrease in perfusion in the apical segments in addition to the basal and mid anterior defects (Figure 4). Given this finding and the concern for ischemia in the territory of these CAAs, after multidisciplinary discussion, the decision was made to obtain a vasodilator stress positron emission tomography-computed tomography (PET-CT). The patient had a resting blood pressure of 96/63 mm Hg with a heart rate of 43 beats per minute, providing a

From the Division of Cardiology, Ann and Robert H. Lurie Children's Hospital of Chicago, Chicago, Illinois (N.D., N.H., M.R.C., S.G.P.); and Northwestern University Feinberg School of Medicine, Chicago, Illinois (N.H., J.J.P., M.R.C., S.G.P.).

Keywords: Transposition of the great arteries, Coronary artery anomalies, Kawasaki disease

Correspondence: Nikkan Das, MD, Ann and Robert H. Lurie Children's Hospital of Chicago, 225 East Chicago Avenue, Chicago, IL 60611. (E-mail: *nikkan.das@gmail.com*).

2468-6441

https://doi.org/10.1016/j.case.2023.12.029

VIDEO HIGHLIGHTS

Video 1: Two-dimensional TTE, parasternal short-axis view, demonstrates a moderately dilated LV (6.2 cm, *Z* score 4.8) with low normal global systolic function (LV fractional shortening 29%).

Video 2: Two-dimensional TTE, apical 4-chamber view, demonstrates a moderately dilated LV (LVEDV 213.6 mL, *Z* score +4.9) with low normal LV global systolic function (LVEF 52%).

Video 3: Cardiovascular magnetic resonance, balanced steady-state free precession sequence, short-axis stack display from base (*top left*) to apex (*bottom right*), demonstrates a mildly dilated LV (LVEDV/body surface area 124 mL/m^2) with low normal systolic function (LVEF 54%) and no regional wall motion abnormalities. Septal motion related to previous cardiac surgery. A mildly dilated RV (RVEDV/body surface area 121 mL/m^2) with normal systolic function (right ventricular EF 55%) is also seen.

Video 4: Invasive coronary angiography with selective injection into the LAD demonstrates 2 areas of consecutive aneurysmal dilation in the proximal LAD, with 50% stenosis in the bend of the artery between the dilated segments.

Video 5: Invasive coronary angiography with selective injection into the RCA demonstrates an anomalous origin of the left circumflex artery arising from the RCA with a posterior course in the left atrioventricular groove. A calcified aneurysm is seen in the mid-RCA and a second noncalcified aneurysm is seen at the bifurcation of the posterior descending coronary artery and acute marginal artery.

View the video content online at www.cvcasejournal.com.

corrected resting flow of 1.0 and a flow reserve of 2.38 that were physiological and within normal limits (Figure 5). There was also a resting perfusion abnormality that was related to a very mild CT phase artifact (Figure 5). This suggested that the abnormal perfusion noted on SPECT was an artifact. The LV systolic function was also normal at stress (LVEF 60%) and low normal at rest (LVEF 53%).

To assess for any potential interventions, the patient underwent invasive coronary angiography, which demonstrated multiple areas of aneurysmal dilation involving the RCA and LAD as described by prior CCT (Videos 4 and 5). The long-segment proximal LAD aneurysm was noted to have a 50% stenosis in between dilated segments. There was no evidence of ostial stenosis. Given these findings of multiple acquired CAAs, a presumptive diagnosis of antecedent KD was made. At 6 months' follow-up, the patient remains asymptomatic on anticoagulation therapy.

DISCUSSION

Kawasaki disease is an acute medium-vessel vasculitis that occurs in children and is associated with CAAs in about 10% of patients in the acute phase.[1] These aneurysms can either regress, persist, recur, or lead to stenotic lesions over time.[2] There are rare case reports of diagnosis of late aneurysms in KD, most of which are associated with localized stenosis.[3,4] However, patients with congenital heart disease, particularly those with a history of coronary artery manipulation, pose additional diagnostic dilemmas in the etiology of late aneurysms.

Transposition of the great arteries is associated with coronary abnormalities, both congenital as well as acquired after the ASO. The ASO involves translocation of the coronary arteries, where the coronary arteries are excised from the native aorta and sutured into the pulmonary artery (neoaorta). Due to this coronary manipulation, patients are at risk of developing coronary artery complications, and lifelong periodic surveillance of the coronary arteries is recommended by current guidelines.[5] Late complications typically include coronary stenosis or occlusion; however, CAAs are not common.[6] One case reported a patient with left coronary artery stenosis with poststenotic

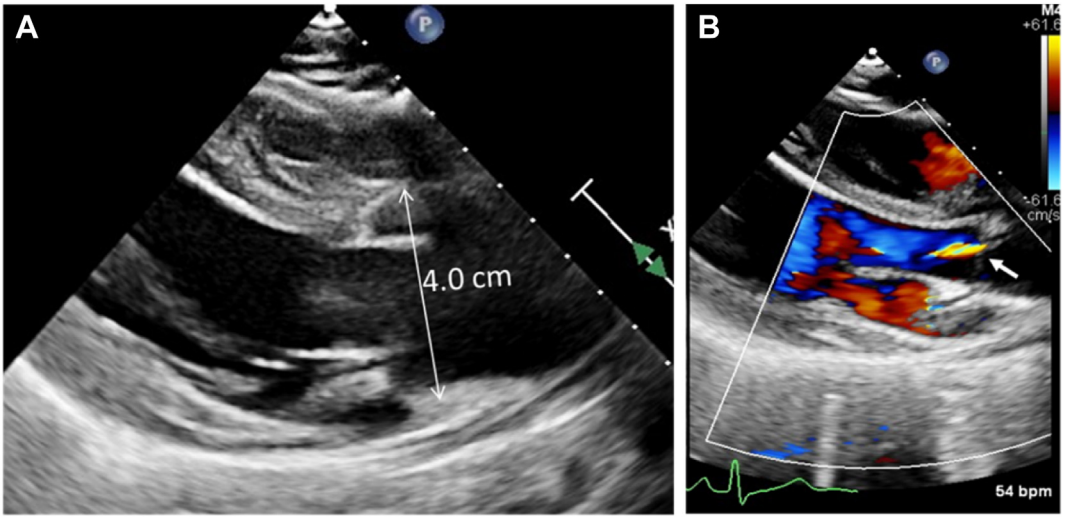

Figure 1 Two-dimensional TTE, parasternal long-axis view in systole without (**A**, *left*) and diastole with (**B**, *right*) color-flow Doppler, demonstrates a moderately dilated neoaortic root (4.0 cm, *Z* score +5.5) with mild aortic regurgitation.

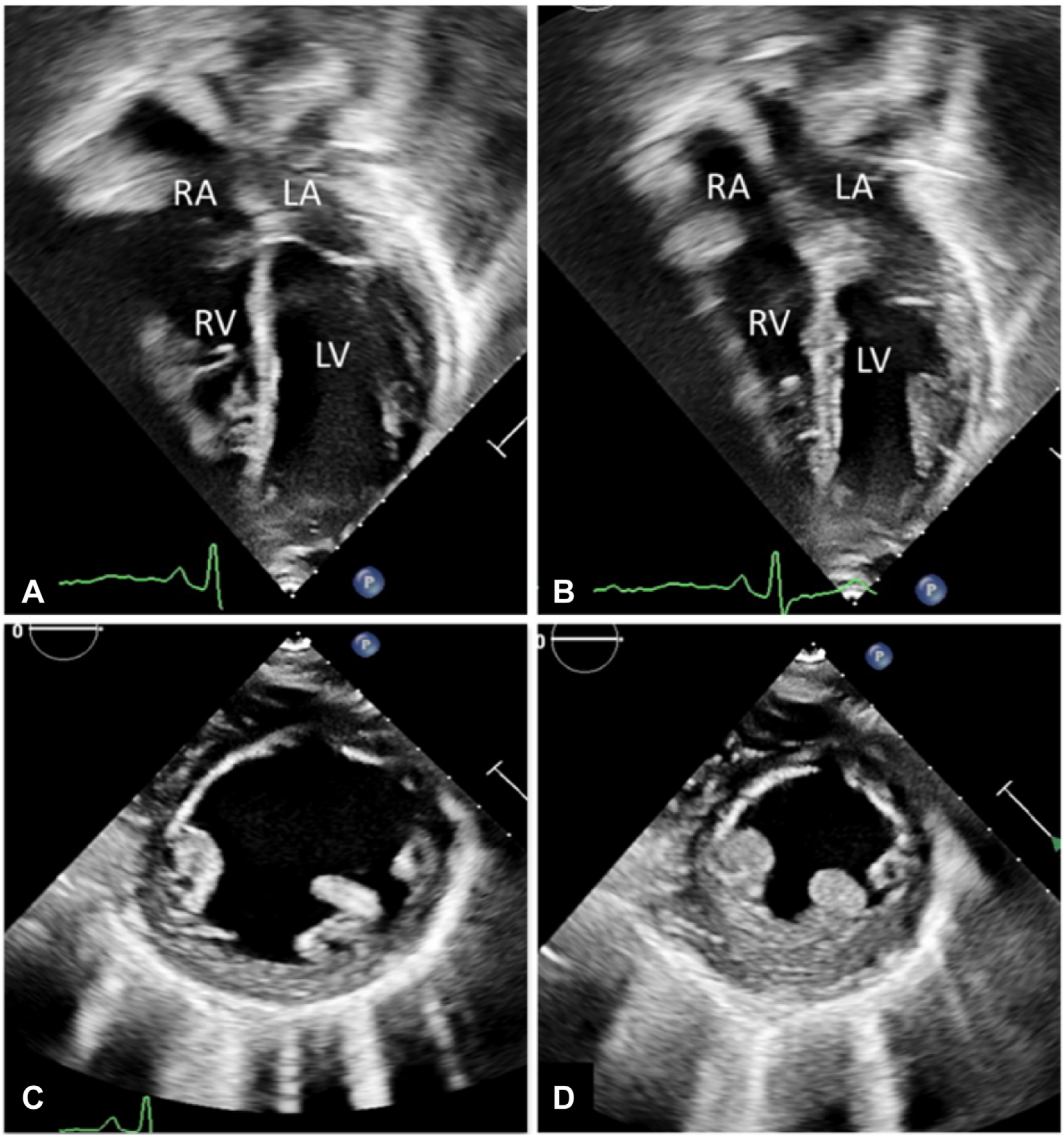

Figure 2 Two-dimensional TTE, apical 4-chamber view in diastole **(A)** and systole **(B)** and parasternal short-axis view in diastole **(C)** and systole **(D)**, demonstrates a moderately dilated LV diameter (6.2 cm, *Z* score 4.8) and volume (LVEDV 213.6 mL, *Z* score +4.9). *LA*, Left atrium; *RA*, right atrium.

aneurysm, which occurred 11 years after the ASO.[7] In our patient, findings of multiple distal CAAs without coronary ostial stenosis or occlusion led to the presumptive diagnosis of antecedent KD.

Current guidelines for surveillance of adult patients with TGA after the ASO acknowledge the difficulty of coronary artery evaluation, as they are often not well imaged on TTE beyond the origins. Additionally, stress imaging with SPECT or CMR lacks sensitivity for detecting coronary blood flow abnormalities in asymptomatic patients. The presence of new coronary abnormalities or the progression of childhood abnormalities is unclear as the long-term natural history is still unknown.[5] A recent review by Engele *et al.*[6] reported that coronary stenosis was found in 5% of asymptomatic patients on routine CCT. They concluded that CCT is a good noninvasive imaging technique for detecting coronary abnormalities in adult patients after ASO.[6] In addition, current guidelines from the American Society of Echocardiography discuss the use of multimodality imaging of these patients.[8] Their recommendations include the use of CMR for routine evaluation of all postoperative patients to assess valve and ventricular function, outflow tracts, branch pulmonary arteries, for imaging the proximal coronaries, and for assessing for inducible ischemia; use of CCT is for patients needing detailed coronary artery evaluation to assess reimplanted coronary arteries for ostial or distal narrowing or kinking and to assess for atherosclerotic disease.

Our patient was found to have a CAA on routine axial imaging more than 10 years after ASO. The finding of an isolated CAA prompted further imaging, which revealed multiple CAAs involving different coronary arteries, with an initial concern for myocardial perfusion abnormalities on SPECT that was resolved by additional testing with PET-CT and cardiac catheterization. However, coronary artery stenosis was not a feature associated with these aneurysms, which raised a concern for the etiology of these aneurysms being unrelated to the history of prior ASO. Although this patient had no

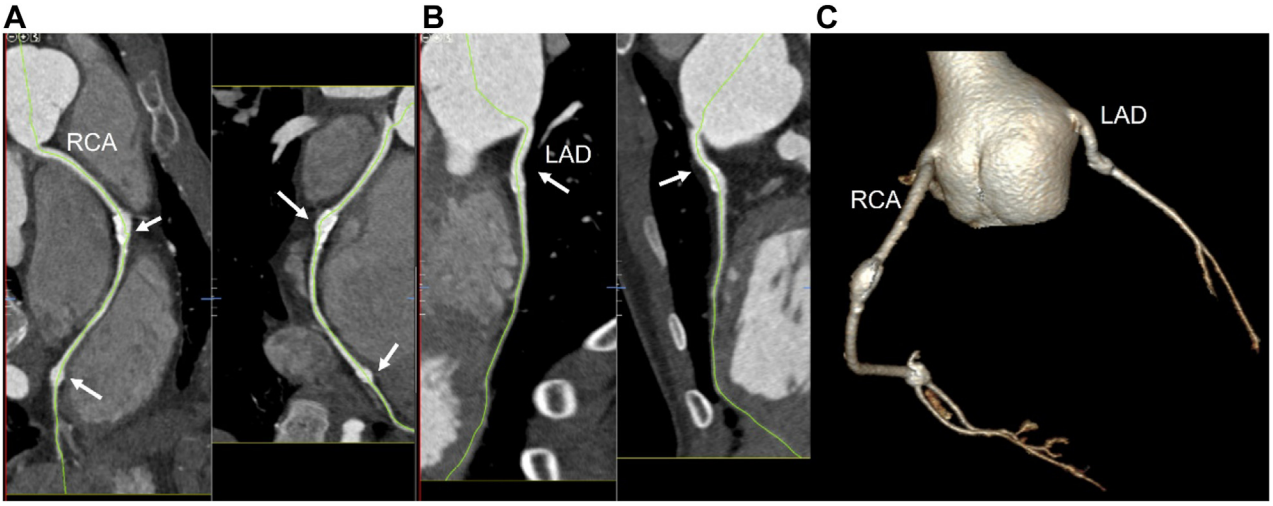

Figure 3 Cardiac computed tomography, curved multiplanar reformatted orthogonal images of the RCA **(A)** and the LAD **(B)**, demonstrates 2 focal severe RCA aneurysms (*arrows*) with associated calcification and a long-segment, moderate aneurysm in the proximal LAD (*arrow*). The three-dimensional volume-rendered reconstruction display **(C)** demonstrates the dilated neoaortic root and the CAA.

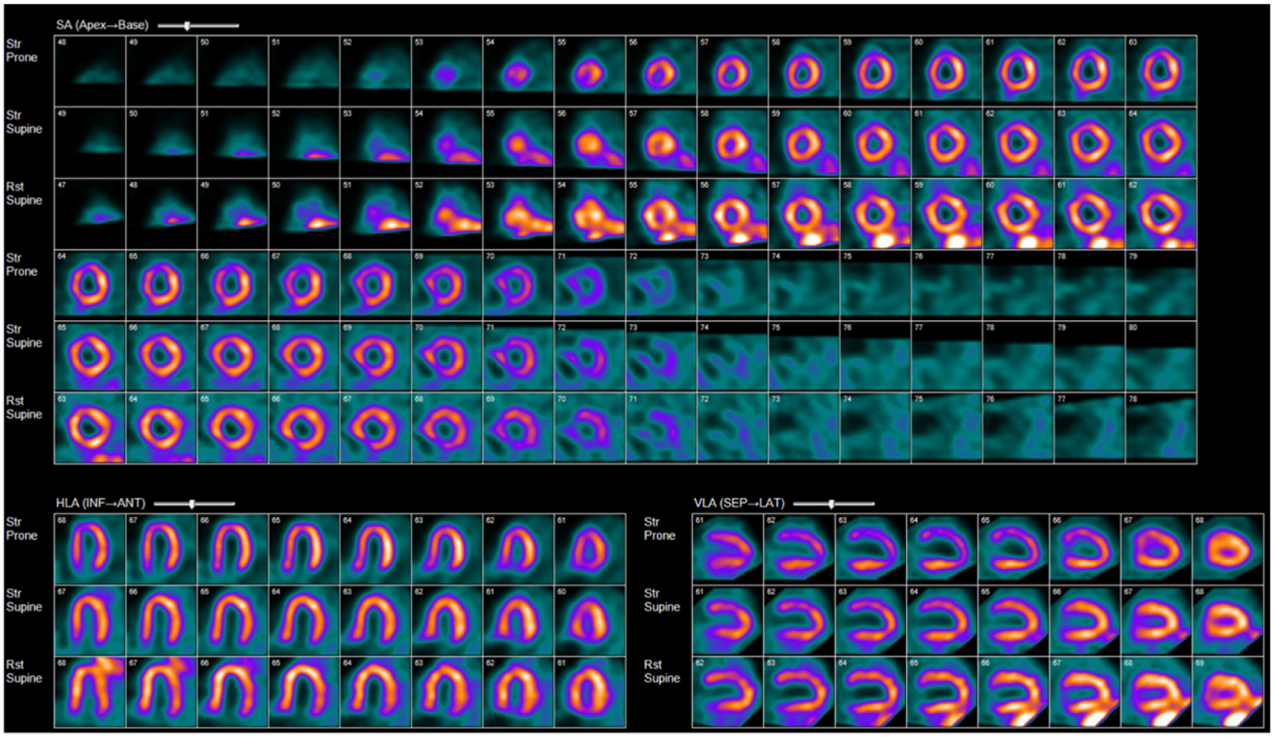

Figure 4 Gated myocardial SPECT perfusion imaging at rest (*top row*) and following exercise stress in the supine (*row 2*) and prone (*row 3*) positions with short axis (SA), horizontal long-axis (HLA), and vertical long-axis (VLA) displays demonstrates a reversible perfusion abnormality in the anterior, basal, midanteroseptal, and apical segments without resolution in prone positioning.

known history of KD, it is the most common cause of CAA in childhood and studies have shown development of late aneurysms.[3,4] In addition, calcifications of the coronary arteries are known to be associated with KD in patients with CAA.[9] Therefore, based on the epidemiology of CAA, a presumptive diagnosis of antecedent KD was made and our patient was treated per the KD guidelines for prevention of coronary artery thrombosis with aspirin and anticoagulation.[10] The utilization of modalities such as PET-CT in patients with both congenital and acquired coronary artery disease has allowed for the identification of microvascular dysfunction in patients without epicardial coronary stenosis, with the additional benefit of providing measures of blood flow reserve and ventricular function.

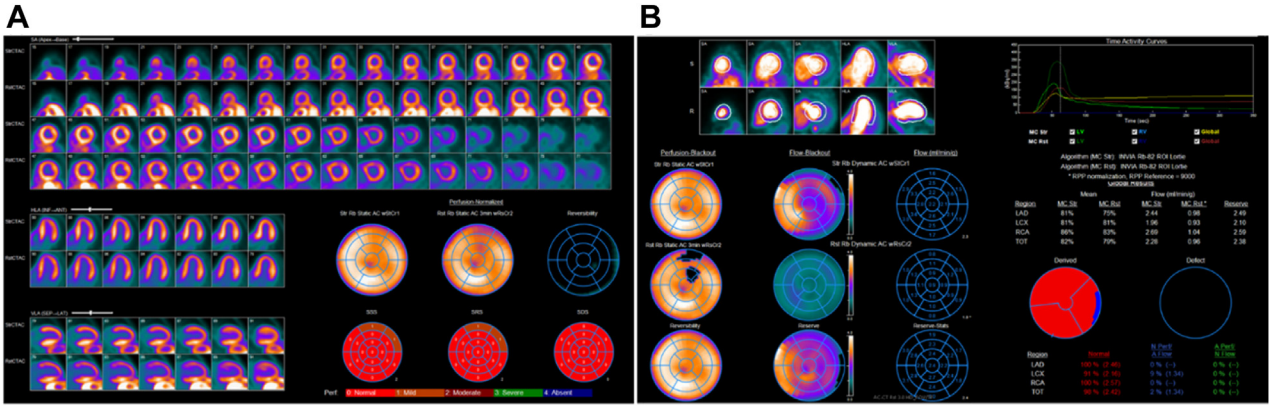

Figure 5 **(A)** Stress and rest Rb-82 PET-CT imaging with attenuation correction in the SA (*top rows*), HLA (*middle*), and VLA (*bottom*) displays with bull's-eye polar maps demonstrates the small-sized, basal anterior, and anterolateral defect on rest that improves with stress. **(B)** Dynamic imaging at stress (S) and rest (R) demonstrates normal global and regional myocardial blood flow reserve with no evidence of ischemia.

CONCLUSION

While echocardiography is the primary modality for serial imaging follow-up in TGA, this case highlights the importance of periodic surveillance of patients after ASO using multimodality axial imaging such as CCT or CMR in coronary artery evaluation. A high level of suspicion of prior KD is required in the development of newly discovered CAAs in adolescence and adulthood.

ETHICS STATEMENT

The authors declare that the work described has been carried out in accordance with The Code of Ethics of the World Medical Association (Declaration of Helsinki) for experiments involving humans.

CONSENT STATEMENT

The authors declare that since this was a noninterventional, retrospective, observational study utilizing de-identified data, informed consent was not required from the patient under an IRB exemption status.

FUNDING STATEMENT

The authors declare that this report did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

DISCLOSURE STATEMENT

The authors report no conflict of interest.

SUPPLEMENTARY DATA

Supplementary data related to this article can be found at https://doi.org/10.1016/j.case.2023.12.029.

REFERENCES

1. Nakamura Y, Yashiro M, Uehara R, Oki I, Watanabe M, Yanagawa H. Epidemiologic features of Kawasaki disease in Japan: results from the nationwide survey in 2005–2006. J Epidemiol 2008;18:167-72.
2. Kato H, Sugimura T, Akagi T, Sato N, Hashino K, Maeno Y, et al. Long-term consequences of Kawasaki disease: a 10 to 21 year follow-up study of 594 patients. Circulation 1996;94:1379-85.
3. Tsuda E, Kamiya T, Ono Y, Kimura K, Echigo S. Dilated coronary arterial lesions in the late period after Kawasaki disease. Heart 2005;91:177-82.
4. Ozawa J, Suzuki H, Hasegawa S, Numano F, Haniu H, Watanabe K, et al. Two cases of new coronary aneurysms that developed in the late period after Kawasaki disease. Pediatr Cardiol 2013;34:1992-5.
5. Stout KK, Daniels CJ, Aboulhosn JA, Bozkurt B, Broberg CS, Colman JM, et al. 2018 AHA/ACC Guideline for the Management of Adults With Congenital Heart Disease: a Report of the American College of Cardiology/American Heart Association Task Force on Clinical Practice Guidelines [published correction appears in Circulation. 2019 Apr 2;139(14):e833-e834]. Circulation 2019;139:e698-800.
6. Engele LJ, Mulder BJM, Schoones JW, Kiès P, Egorova AD, Vliegen HW, et al. The coronary arteries in adults after the arterial switch operation: a systematic review. J Cardiovasc Dev Dis 2021;8:102.
7. Marini D, Defilippi C, Agnoletti G. Left coronary artery stenosis with post-stenotic aneurysm after arterial switch operation before and after coronary revascularisation surgery. Cardiol Young 2011;21:456-7.
8. Cohen MS, Eidem BW, Cetta F, Fogel MA, Frommelt PC, Ganame J, et al. Multimodality imaging guidelines of patients with transposition of the great arteries: a report from the American Society of echocardiography developed in Collaboration with the Society for cardiovascular magnetic resonance and the Society of cardiovascular computed tomography. J Am Soc Echocardiogr 2016;29:571-621.
9. Tsujii N, Tsuda E, Kanzaki S, Ishizuka J, Nakashima K, Kurosaki K. Late wall thickening and calcification in patients after Kawasaki disease. J Pediatr 2017;181:167-1712.
10. McCrindle BW, Rowley AH, Newburger JW, Burns JC, Bolger AF, Gewitz M, et al. Diagnosis, treatment, and long-term management of Kawasaki disease: a scientific statement for health professionals from the American heart association [published correction appears in Circulation. 2019 Jul 30;140(5):e181-e184]. Circulation 2017;135:e927-99.